ATTENUATION ANALYSIS FOR NON-MONOCHROMATIC SOURCES

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This document describes a sample analysis for extinction of electromagnetic radiation from non-monochromatic sources in media where attenuation lengths are expected to vary as a function of wavelength. Dramatic deviations from exponential decay appear across the absorption edges of materials such as Linear-Alkyl-Benzene, which is of interest to experiments using this organic solvent for metal-loaded organic scintillators in the next generation of neutrino experiments.

THE ELECTRONIC DETECTOR GROUP at BNL has developed a simple 2 meter system for determining the extinction of electromagnetic radiation in the near-uv in liquid samples. Measurements with this system have revealed a systematic effect that causes light yields to deviate from an exponential extinction on the order of 1 percent. 1 Various models of scattering phenomena have been used to explain this deviation with marginal statistical significance. If the emission spectra of a source is co-incedent with an absorption edge in the material (i.e. where the absorption varies dramatically over a short wavelength range), a convolution of exponentials with support in the spectral profile reveals just such an effect.

$$I(x) = I_0 \frac{\int F(\lambda) e^{\frac{-x}{l(\lambda)}} d\lambda}{\int F(\lambda) d\lambda} \qquad (1)$$

LINEAR-ALKYL-BENZENE has been chosen as the organic solvent for metal-loaded organic scintillators in many of the next generation neutrino experiments on the basis of its optical transparency, low cost and excellent dissolution of organic-metal complexes. A typical absorption curve for purified and unpurified samples indicates that the expected attenuation length in the near-ultraviolet is several meters.

Absorption is defined $A = -\log_{10} \frac{I_0}{I} = \epsilon CL$. Where L is the path length through the material at which A is determined. Conversion of absorption to attenuation length is done by converting from base 10 to the natural number: $l = \frac{0.434L}{A}$

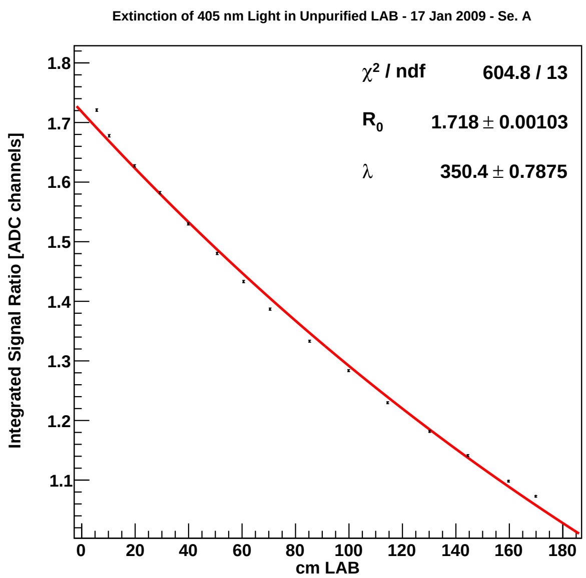

Figure 1: A sample data set from extinction measurements taken at the BNL 2-m system.

Detailed extinction data at optical wavelengths in the near-uv are required to make sense of future in-situ measurements of light extinction in antineutrino detectors. Since this monitoring equipment will typically consist of LEDs with a wide emission spectrum, it is worthwhile to understand how measurements should be expected to vary from more precise measurments taken at single wavelengths when characterizing scintillator batches at the time of production.

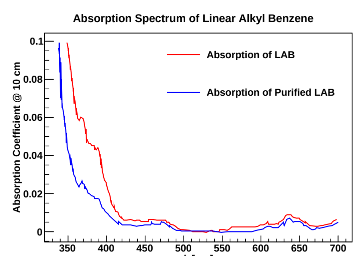

Figure 2: Absorption spectra of purified and un-purified LAB samples from a desktop UV-vis spectrometer in Dr. Yeh's laboratory

SIMULATIONS OF LIGHT EXTINCTION with monochromatic and measured spectral profiles have been made to compare with data taken with the BNL system in accordance with 1. Typical spectra for the light sources used are compared with the absorption curve of unpurified LAB in Figure 3.

LEDs LED405E and LED470E are available from Thorlabs. The spectra provided here are manufacturer spec, and may vary from LED to LED. The 430 nm GaN-SiC spectrum is from a Nichia model at http://ledmuseum.home.att.net. The measurement differs from official manufacturer specs, thus, this spectrum has not been included in the following simulation.

A comparison of light yields as a function of path length through LAB is shown in Figure 4. The light yield for the 405 nm LED differs substantially from a simple exponential as shown in Figure **??**. This is due to the large variation in absorption across the lower half of the emission spectrum. It is important to note that LEDs pulsed at short widths ($< 1\mu$s) typically narrow their spectrum and shift towards the UV. It is critical then, that the led spectra

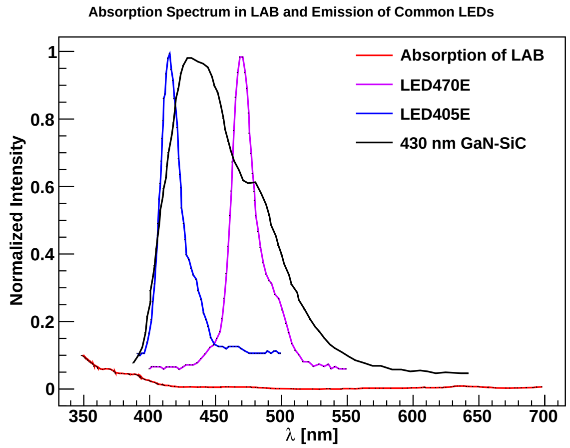

Figure 3: LED emission spectra with LAB absorption curve overlayed.

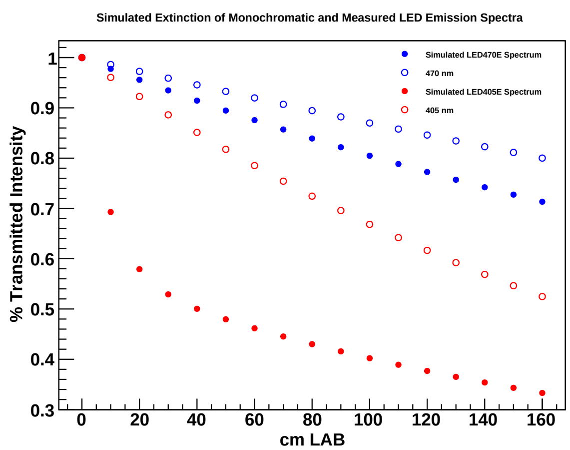

Figure 4: Simulated extinction of monochromatic and LED spectra.

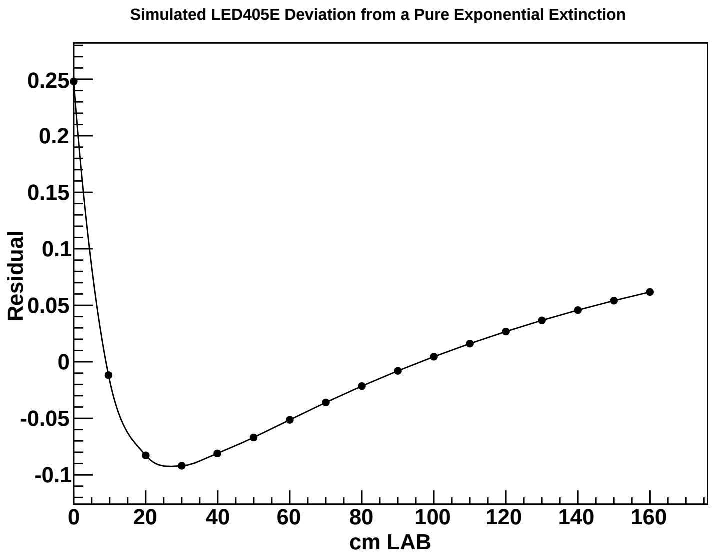

Figure 5: Residual values from an exponential fit to the simulated LED405E spectrum.

be measured as pulsed at the time of measurement if they are to be compared with data either in the 2-m system or from online monitoring. The residuals determined from the best fit parameters 5 exhibit the typical "smile" observed in the 2-m system, though the simulated effect appears to be much larger. This is likely due to the absorption data used for the simulation, which was taken with a desktop UV-vis spectrometer operating near the edge of it's dynamic range. Also, PMT quantum efficiencies have not been modelled, but this is not expected to be a large effect due to the dual beam reference technique we employ.

To MINIMIZE THESE EFFECTS narrow band pass filters have been installed between all light sources and the beam splitter. Equation 1 can also be used to correct these systematic errors. With a measurement of the emission spectrum F(λ) is determined and deviations from a power law can be attributed to $l(\lambda)$, provided scattering effects are small or uniform over the band pass region. If the function $l(\lambda)$ is assumed to be approximately linear in the region centered on the band pass then we can expand equation 1:

$$I(x) = I_0(0.68e^{\frac{-x}{l_c-\alpha\epsilon}} + e^{\frac{-x}{l_c}} + 0.68e^{\frac{-x}{l_c+\alpha\epsilon}}) \tag{2}$$

where l_c αandϵ are taken to be the central attenuation length, the slope of $l(\lambda)$ and the FWHM of F(λ) respectively. New data is forthcoming.